Intel and AMD Diverge on 64-Bit Platforms

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Agenda

- What Makes a Processor '64-Bit'?
- Intel's Approach to 64-Bit Computing
- AMD's Approach to 64-Bit Computing
- Imponderables to Keep You Awake at Night
- Handicapping the 64-Bit Performance Race

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Why Does 64-Bittedness Matter?

- Large Memories Have Become Affordable
- 4 GB of PC100 Memory Costs ~ $4,000 at Current DRAM prices
- A 32-Bit Processor Can Only Address up to 2^{32} (4,294,967,296) Memory Locations
- A 64-Bit Processor Can Directly Address 2^{64} (18,446,744,073,709,551,616) Locations

Why Would Anyone Need >4 GB Main Memory?

- Bigger CAD Models
  - 100 Million Transistor Chips
  - Complete Airplanes/Ships/Autos
- Bigger Databases
- Bigger Memory-Resident Databases (Improved Transaction Performance)
- Bigger Images at Higher Resolutions
- No Obvious Fit With Today's High Volume Desktop Applications

What Makes a Computer "64-Bit?"

- Key 64-Bit Attributes:
  - 64-Bit Virtual Addressing
  - 64-Bit Integer Arithmetic
- Irrelevant Attributes:
  - Instruction Set Architecture (CISC/RISC/EPIC)
  - Width of Physical Memory Addresses
  - Width of Physical Memory
  - Width of I/O and/or Memory Buses

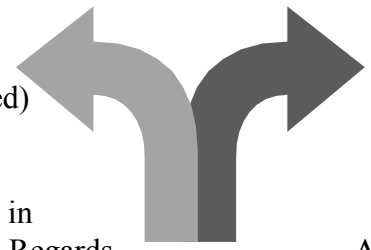
Can 32-Bit Designs be Extended 'Transparently' to 64-Bits?

- NO!
- Programs MUST Be Modified to Accommodate 64-Bit Addressing
- At a Minimum, 32-Bit Programs Must Be Recompiled to Use 64-Bit Features
- OS Software Must be Cognizant of 64-Bit Machine Environment
- Any Workable Transition to 64-Bits Must Accommodate Existing 32-Bit Applications

Two Roads Diverge

intel

- Itanium (aka Merced)
- IA-64
- EPIC
- Unlike x86 in Almost All Regards



AMD

- Sledgehammer (aka K8)
- X86-64
- CISC
- Like x86 in Almost All Regards

Intel's 64-Bit Philosophy

- **Once In A Lifetime Opportunity to Introduce New Mainstream Architecture**
  - **Maximize New Technology Included**
  - **Build A Solid Base for 25-Year Evolution**
- **Invest in Tools to Assure Smooth Industry Transition**
  - **$250 Million IA-64 Fund**
  - **25 Application Solution Centers**
  - **Extensive Pre-Silicon Simulation Environments**

Intel's 64-Bit Platform Strategy

- Target High End of Workstation/Server Market Now Dominated by Proprietary RISC Systems (MORPs)
- Gain Broad OEM Acceptance
- Develop Basic MPU/Chipsets/ Motherboards In-House
- Work with Industry to Address All Key Areas of Server Design:
  - I/O, Chasses, 3rd-Party Core Logic, OS Support, Applications, et al.

Intel's 64-Bit Hardware Strategy

- New IA-64 Architecture
  - EPIC-Based (VLIW-Like)
  - Performance Highly Dependent on Compiler Technology
- Four New IA-64 Processors in Development
  - Merced (Mid '00, 0.18m Aluminum)
  - McKinley (End '01, 0.18m Aluminum)
  - Deerfield (End '02, 0.13m Cu)
  - Madison (End '03, 0.13m Cu)

Intel's 64-Bit Software Strategy

- Five New Software Environments
  - Windows 2000-64, Modesto (Novell)
  - Three Unix Variants: Monterey, Linux, Solaris
- Encourage/Facilitate IA-64 Ports of Major Application Packages
  - Oracle 8i, SQL, SAP, SoftImage, Nastran, etc.

Intel's 32-Bit Compatibility Strategy

- IA-64 CPU Includes Separate IA-32 Instruction Decode/Execution Facilities
- Map IA-32 Registers onto IA-64 Register Set
- Inter-Modal Calling Mechanisms Allow IA-32 and IA-64 Programs to Call One Another
- Optimize CPU for 64-Bit Code Performance
  - Intel's 32-Bit Processors (Coppermine and Willamette) Will Be Faster in Pure 32-Bit Environments

AMD's 64-Bit Philosophy

- Provide One Chip that Maximizes Performance of 32-Bit *And* 64-Bit Software
  - 32-Bit Addressing is Enough for Most Programs
  - Only a Small Number of Applications Need 64-bit Address Spaces
  - Preserve the Massive 32-Bit Software Base and Eliminate the Need to Rewrite These Programs
  - Let Users Mix and Match 32-Bit and 64-Bit Programs without Performance Penalties

AMD's 64-Bit Platform Strategy

- Target Mid-Range Workstation/Server Markets Now Dominated by Proprietary RISC And Intel Xeon Systems
- Provide 64-Bit Features at a Small Incremental Cost to 32-Bit Systems
- Build a Large Base of 64-Bit Capable Systems Purchased for 32-Bit Applications
- Use the Large Installed Base of x86-64 Systems to Attract ISV Support

AMD's 64-Bit Hardware Strategy

- New x86-64 Architecture
  - Straight-Forward Extension of 32-Bit x86
  - New, Register-Oriented Floating-Point HW
- New x86-64 Processor in Development
  - SledgeHammer (2H'01, 0.18m, Copper)
    - 5% Die Size Penalty for 64-Bit Features
    - May Utilize Then-Existing AMD Core Logic and Motherboards
    - Will Share Many 'LDT' Bridges and Controllers With 32-Bit Processors

AMD's 64-Bit Software Strategy

- AMD Hasn't Articulated Its Strategy
- My Assumptions:
  - Windows 2000-64 Is *Essential*
  - Linux Is *Essential*
  - Monterey Would Be *Nice*
- ISV's That Need Large Address Space Might Port SW
- ISV's That Don't Need Large Address Space Won't Bother to Port SW
  - But Their 32-Bit Software Won't Run Faster on Any Other AMD Processor

AMD's 32-Bit Compatibility Strategy

- A Single Instruction Decoder Handles 8-, 16-, 32- and 64-Bit Instructions
- A Single Register File Stores 8-, 16-, 32- and 64-Bit Data
- Intended to Be AMD's Fastest Processor When Executing 32-Bit Code or 64-Bit Code
  - Just as 386, 486 and Pentium Were Intel's Fastest 16-Bit *AND* 32-Bit Processors

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Intel Imponderables

- How Quickly Will OEMs Migrate to IA-64?
- How Quickly Will End-Users Migrate to IA-64?
  - Everything is New
  - Target Markets are Risk-Averse
  - Lackluster 32-Bit Performance a Potential Snag
- How Quickly Will ISVs Port to IA-64?
- Can IA-64 Compilers Keep IA-64 Hardware Pipelines Busy?

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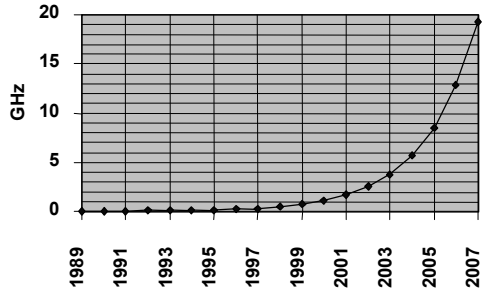
AMD Imponderables

- Will End-Users Migrate to x86-64?
  - Target Markets are Risk-Averse
  - AMD a New Entrant in High-End Systems
- Can AMD Attract Key OEMs to x86-64?
- Will ISVs Port to x86-64?
  - ISVs Reluctant to Support Alternative Architectures
- Can AMD Achieve Industry-Leading 64-Bit *And* 32-Bit Performance in the Same Chip?

Industry Imponderables

- Will 64-Bit Addressing Enable New High Volume Desktop Applications?
- Will MPU Clock Frequencies Continue to Increase ~50%/Year?



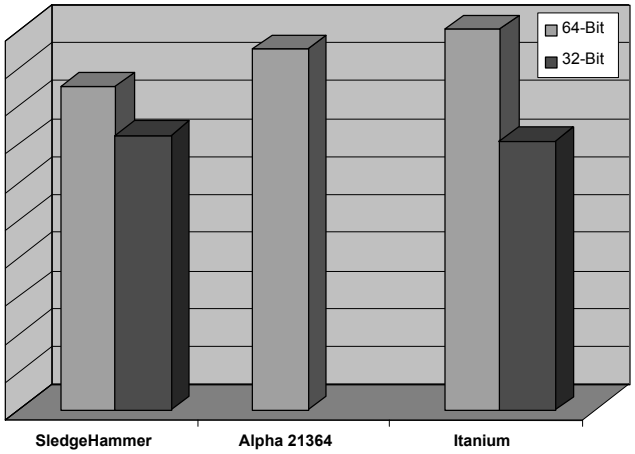
The 2001 CPU Performance Derby

- There's More to *System* Performance than the Speed of a *Single* CPU
  - Memory Bandwidth, Bus Bandwidth, Multi-Processor Switching and Interconnect, Scalability, etc., etc.
- There's More to System Value than the Speed at which a Program Executes
  - Price, Software Availability, Vendor Support, Reliability, Supplier Roadmaps, Supplier Experience, Yada, Yada, Yada

The 2001 CPU Performance Derby (continued)

- It's Easier to Win an MP System Benchmark If You Have the Fastest Uni-Processor Performance
- The Contestants:
  - Alpha 21364
  - AMD SledgeHammer
  - Intel IA-64 (Itanium, Itanium II?)
  - (With Apologies to Sun, SGI and HP…)
- And the Winner is …

Itanium > Alpha > SledgeHammer?



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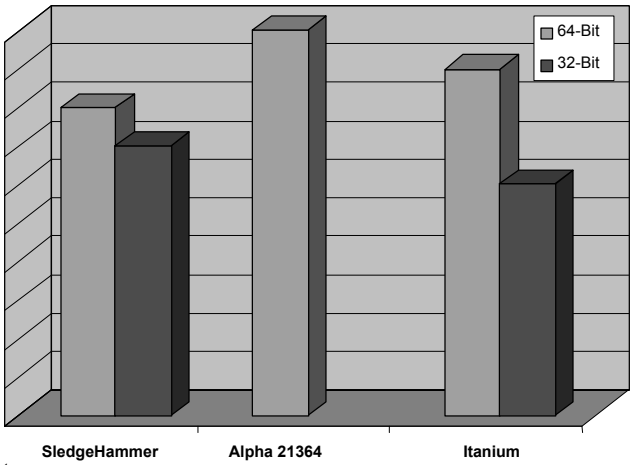
Alpha > Itanium > SledgeHammer?



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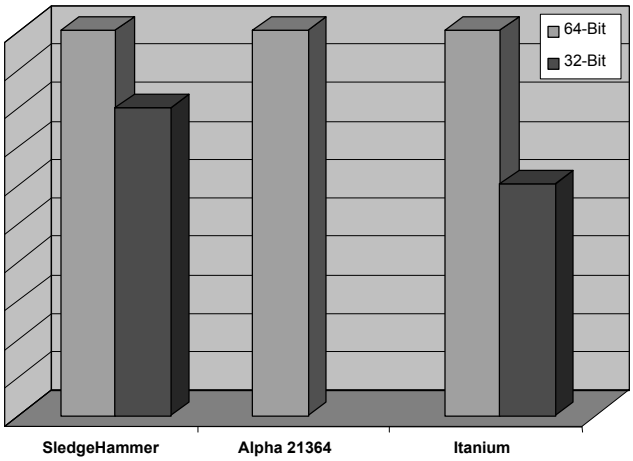
Alpha = Itanium = SledgeHammer?



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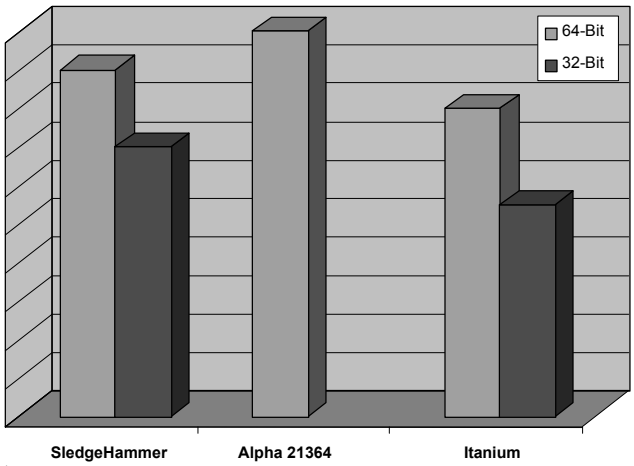

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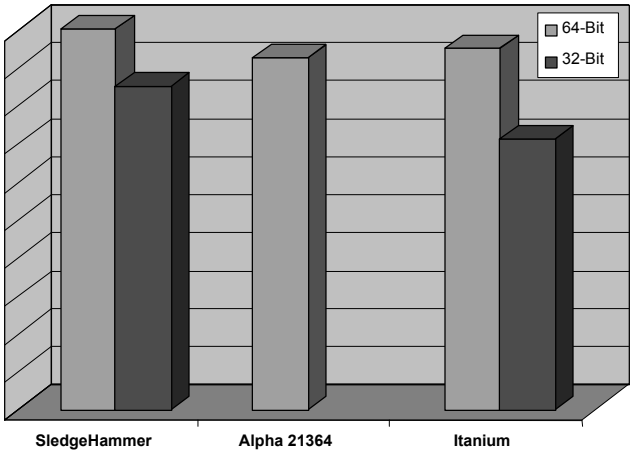
SledgeHammer > Itanium > Alpha?



Summary

- 64-Bit Computing Forces a Break with 32-Bit x86 Binary Compatibility
- Intel's 64-Bit Architecture Represents a Radical Departure from 32-Bit x86 Designs
- AMD's 64-Bit Architecture Minimizes Changes to the 32-Bit Environment
- It's Too Early to Predict Which Approach Will Yield the Best Performance
- Performance is Only One of Several Factors that Will Determine Long-Term Success